A-0611

MODEL 120D
PULSE GENERATOR

SERIAL NOS. PREFIXED A

E-H RESEARCH LABORATORIES, INC.
163 ADELINE STREET · OAKLAND 20, CALIFORNIA

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SECTION I
SPECIFICATIONS

1.1 GENERAL

The new E-H Model 120D is a flexible, fast, double Pulse Generator which is quality engineered to meet high performance standards. The fast rise time and high repetition rate make it unexcelled for general laboratory use in development, production and testing of diodes, fast transistors, cables, delay lines, pulse transformers, and video amplifiers ... for development and design work in the computer field, and for rf and nuclear applications.

REPETITION RATE - 100 cps to 10 mc meeting all specifications and useful pulse output to 20 mc, internally controlled. (See Note regarding 20 mc repetition rates.) The instrument may be externally driven from zero to 20 mc.

OUTPUTS - There are two outputs. The amplitude of each is independently and continuously variable from 2 to 20 volts, negative. The outputs are AC coupled and have a characteristic impedance of 50 ohms. (Use E-H Model ZT Pulse Transformers to invert the pulse and match to other impedances.)

RISE TIME - Rise time is a function of amplitude. At 10 volts output the rise time is less than 0.85 ns--typically 0.7 ns. At 20 volts amplitude the rise time is less than 1.5 ns--typically 1.2 ns. Fall time is approximately 1 ns at 10 volts output and 2 ns at 20 volts output.

PULSE WIDTH - 10 to 100 ns, continuously variable by coarse selector and fine vernier front panel control. The widths of both output pulses are controlled simultaneously and are identical.

DUTY CYCLE - 15% maximum duty cycle. An overload relay with front panel indication and reset automatically protects the instrument from damage from excessive duty cycle.

TRIGGER - For sync purposes, a negative trigger pulse approximately 4 volts in amplitude and approximately 100 ns wide is provided. The trigger is 120 ns advanced with respect to the output pulse for convenient use with sampling oscilloscopes.

EXTERNAL DRIVE - A 4 volt negative pulse is required to externally drive the Model 120D.

GATE - A negative 5 volt signal applied to the gate input will interrupt the pulse train for the duration of its presence.

DIMENSIONS -

Cabinet mounted:	6" high, 17" wide, 12" deep
Rack mounted:	7" high, 19" wide, 12" deep
Weight:	27 lbs. net; 34 lbs. packed; 46 lbs. packed for export.

NOTE

The Model 120D incorporates the most advanced design techniques and components. However, between 10 and 20 mc, some width variation with change in repetition rate will occur and the maximum pulse width will decrease to 7.5 ns at 20 mc (15% duty cycle).

1.2 ACCESSORIES

Use Model RT Rise Time Integrators to obtain precise rise times in applications where responses to slower rise times are important. Standard rise times are 5, 10, 20, 50, and 100 nanoseconds; other values on special order. Coaxial body with BNC connectors. Price $35.

Use Model ZT Pulse Transformers to match to impedances other than 50 ohms. Standard impedances are any combination of 50, 93, 125, 185 or 200 ohms, normal or inverting. Coaxial body with BNC connectors. Price $35.

Use a Model 921 Variable Delay Generator between an external driving source and the Model 120D to obtain precision pulse positioning; or between two or more Model 120D's. Continuously variable delays from 50 nanoseconds to 100 microseconds. Price $425.

Use Model DT D-C Restorer to change the A-C coupled output of the Model 120D to a D-C coupled output. The output of the Model DT is very fast and clean. Price $60.

E-H manufactures a broad line of pulse generating instruments and accessories. Ask your local E-H representative for a demonstration.

1.3 SPECIAL MODIFICATIONS

The Model 120D can be modified to provide a trigger advance to the customer's specifications. (120 nanoseconds is standard; 200 nanoseconds is maximum.)

The Model 120D-2 is a modification to provide pulse widths from 3 nanoseconds to 10 nanoseconds by external clipping lines. Clipping lines for pulse widths of 3 nanoseconds and 5 nanoseconds are provided. Both the leading edge and the trailing edge of the normal output pulse are clipped, providing a negative/positive pulse pair the separation of which is determined by the front panel WIDTH controls. If the pulse pair is undesired, the Model DTN or DTP will eliminate the undesired pulse. Maximum pulse amplitude is 10 volts when clipping lines are in place. When clipping lines are disconnected, operation is normal and all standard specifications apply.

TOP: Channel 1 Rise Time 1.1 nanoseconds at 20 volts amplitude.

BOTTOM: Channel 2 Rise Time 1.2 nanoseconds at 20 volts amplitude.

SECTION II
OPERATING INFORMATION

2.1 OUTPUT IMPEDANCE

The Model 120D is a current source designed to operate into a 50 ohm resistive load. If the instrument is terminated in other than 50 ohms, a mismatch will occur -- resulting in excessive overshoot and waveform distortions. Operation of the instrument unterminated (open-circuit) will seriously reduce the life and performance of the output tubes.

In order to deliver all available power to the external load, the outputs of the Model 120D have not been backmatched in 50 ohms. The impedance looking into the output connectors is actually very high. In some applications backmatching may be necessary, and a 50 ohm pad can be placed across the output connector.

2.2 DC RESTORATION

The output of the Model 120D is A-C coupled in order to provide the fastest possible rise time. D-C restoration is possible with E-H Model DT D-C Restorer. A brief description of the Model DT will be found in paragraph 1.2, Section I.

2.3 CABLES, CONNECTORS AND ATTENUATORS

The sharp rising pulse of the 120D has appreciable frequency components up to 1 kmc. If any of these high frequency components are attenuated through the use of connectors, cables, or attenuators that do not have a flat frequency response to frequencies in excess of 1 kmc, the result will be a degradation of the pulse rise time. Mismatch effects can also degrade the pulse waveform. Consequently, some consideration and care must be taken to preserve the quality of the pulse output of the Model 120D when coupling it to the system or device under test.

Some of the precautions to observe in coupling the Model 120D pulse outputs are:

1) Always terminate the output of the Model 120D in a 50 ohm resistive load.

2) If the input impedance of the device or system under test is other than 50 ohms, use an impedance matching device so that mismatch effects will not degrade the pulse waveform.

3) Make sure that all connectors, attenuators, and cables are of proper impedance and have a flat frequency response in excess of 1 kmc. The GR and Tektronix coaxial attenuators are recommended for use, as well as the GR Type 875 hermaphrodite coaxial connectors. Only 50 ohm cable should be used at the Model 120D BNC output connectors. RG-8A/U cable is recommended. Both RG-58A/U and RG-174/U will cause appreciable loss of rise time if lengths larger than a few inches are used.

2.4 MEASURING RISE TIME AND WAVEFORM

The pulse characteristics of the Model 120D can best be observed on the Tektronix Type 519 or Type 661 oscilloscopes. The very fast rise time of these oscilloscopes (about 0.35 nanoseconds) and their clean pulse response make them the recommended instruments for observing the Model 120D characteristics.

Reasonable precautions must be taken in connecting the pulse generator to the oscilloscope. (See paragraph 2.3 above.) The Type 519 oscilloscope should be internally synchronized, rather than externally. (See paragraph 3.4, Section III.) In addition, the sweep speed of the oscilloscope should be calibrated so that rise time can be measured accurately. The rise time specification is tested at the factory with the waveform controls adjusted to provide 5 per cent overshoot.

When measuring rise time, it is important to take into consideration the rise time of the oscilloscope.

For gaussian functions the rise time observed on the oscilloscope is, to a first approximation, equal to the square root of the sum of the squares of the oscilloscope rise time and the pulse rise time of the Model 120D.

TABLE I
OPERATING CONTROLS

CONTROL	OPERATION
FREQ. RANGE	The internal repetition rate is controlled by a coarse FREQ. RANGE selector which is calibrated in decade steps (except for the 10 to 20 mc range). The FINE control provides continuous coverage within the selected decade range.
WIDTH	The coarse WIDTH selector switch and FINE control vary the width of the output pulses from 10 to 100 nanoseconds.
AMPLITUDE	These continuous controls independently select the amplitude of the pulses received from channel 1 and channel 2.
WAVEFORM	A screw driver adjust waveform control for each output channel is located on the rear panel. This control determines the amount of overshoot and, to some extent, the waveform of the first 10 to 15 nanoseconds of the output pulse. It also has an effect on pulse amplitude. The control should be adjusted while observing the output pulse on an oscilloscope. Once it is adjusted as desired, it should not need readjustment unless a component in the output chain is replaced.
OVERLOAD RESET	This is a visual indication that the 15% duty cycle limitation has been exceeded. The duty cycle should be corrected and the reset button pushed to restore normal operation.
PULSE OUTPUT	Each connector provides an independent pulse train designed to operate into a 50 ohm resistive load.
TRIGGER OUTPUT	The trigger output is a negative 4 volt pulse typically 100 nanoseconds wide. It is directly coupled to the front panel BNC connector through 510 ohms. The trigger output should not be connected to any active device. The signals generated by an active device can interfere with the timing circuitry of the Model 120D.
GATE INPUT	A negative 5 volt signal is required to gate the instrument. If the gating frequency is not synchronized with the pulse repetition rate, one spurious pulse can occur immediately after the gating signal is removed. There can be some DC shift in the pulse chain after it is gated under certain conditions. These conditions are low gating frequency and high duty cycle.
EXT. DRIVE INPUT	To drive the instrument externally, the FREQ. RANGE selector must be set to EXT. and a negative 4 volt trigger applied to the EXT. DRIVE INPUT connector. With the FREQ. RANGE selector set to EXT., the FINE frequency functions as a trigger sensitivity control. As the control is rotated clockwise, the input becomes increasingly sensitive to an external drive trigger. At a fully clockwise position the instrument will typically free-run.
AC	For optimum life the AC switch should be turned on at least 30 seconds before the DC switch.

For example:

Observed rise time = 0.8 nanoseconds

Scope rise time = 0.35 nanoseconds

Pulse rise time = $\sqrt{(0.8)^2 - (0.35)^2}$

$= \sqrt{0.64 - 0.12}$

$= \sqrt{0.52}$

= 0.72 nanoseconds

The word "gaussian" is underlined in the previous paragraph because some sampling oscilloscopes do not have a gaussian rise. With these samplers the effect of the oscilloscope on the rise time being measured cannot be taken into account so simply. The Tektronix Type 519 and 661 do have an approximate gaussian rise.

Even when great attention is paid to cabling and impedance matching, it is likely that some waveform deviations will be observed on the oscilloscope presentation which are not present at the Model 120D output connectors. Considerable judgment must be exercised in interpreting the oscilloscope presentation. Several observations should be made under different measuring conditions to help in determining what part of the oscilloscope presentation is due to mismatch effects and oscilloscope characteristics (rise time, overshoot, amplifier linearity, etc.).

Some of the pulse characteristics you are likely to observe on a 10 volt amplitude pulse are as follows:

1) Approximately 0.6 volts preshoot.

2) Pulse top distortion of less than 1 volt peak-to-peak. This distortion occurs in the first 10 or 15 nanoseconds of the pulse, and its shape is somewhat variable by the waveform control. The remainder of the pulse top is essentially free of distortion.

3) Distortion of approximately 1 volt peak-to-peak amplitude of the base line immediately after the pulse.

4) No sag.

5) No ringing.

6) Variable overshoot (waveform controls).

Observation of characteristics appreciably different from those listed above will usually be traceable to the measurement apparatus. Reflections that have a period of 5 nanoseconds may be traceable to a mismatch at the instrument's output connector, since 5 nanoseconds is the approximate propagation time of the internal cable which connects the plate of the output tube to the output connector.

2.5 PULSE WIDTHS LESS THAN 10 NANOSECONDS

The minimum specified pulse width of the Model 120D is 10 nanoseconds. However, the instrument can deliver pulses narrower than 10 nanoseconds width by appropriate adjustment of the width controls and the variable timing capacitor C58. Usefulness of the pulses at widths narrower than 10 nanoseconds is limited primarily by three effects.

1) The rise time tends to become slower as the width is decreased to 6 or 7 nanoseconds.

2) Jitter begins to appear on trailing edge of pulse as width is decreased much below 10 nanoseconds.

3) There is characteristically a considerable amount of width variation with repetition rate at widths below 10 nanoseconds.

2.6 PULSE WIDTHS GREATER THAN 100 NANOSECONDS

Although specifications limit the maximum pulse width of the 120D to 100 nanoseconds, the instrument will deliver wider pulses. Typically, the maximum pulse width is approximately 140 nanoseconds. At low duty cycles these wide pulses have no aberrations. However, a 140 nanosecond wide pulse will start to sag as duty cycle is increased to approximately 10 or 11% and the sag becomes increasingly pronounced as the duty cycle increases further.

2.7 DUTY CYCLE EFFECTS

Over the specified range of pulse widths and amplitudes there is very little duty cycle effect. Typically, pulse amplitude decreases about 10% and pulse width a few per cent as the duty cycle is increased from essentially zero to 15%. There is no degrading of pulse rise or fall times as a result of duty cycle, and there is typically less than 5% pulse sag at 100 nanoseconds width and 15% duty cycle.

The duty cycle limitation is to insure long tube life by conservative operation of the tubes. The overload relay is typically adjusted so that duty cycles a little in excess of the rated 15% are available -- the exact overload tripping point being a function of the amplitudes of the two output pulses. With both pulses at maximum amplitude the limiting occurs at very nearly 15% duty cycle. With both pulse amplitudes at minimum duty cycle, limiting will occur at 18-20%.

If slightly higher duty cycles are required, they can be obtained at the expense of tube life by increasing the value of resistor R203 on the overload relay. In no event can the instrument be modified to provide greater than 20% duty cycle with both pulse amplitudes set to 20 volts. Amplitude and width variations with duty cycle will be more pronounced if the instrument is modified to operate at duty cycles higher than 15%. However, there should be no change in rise time or pulse waveform.

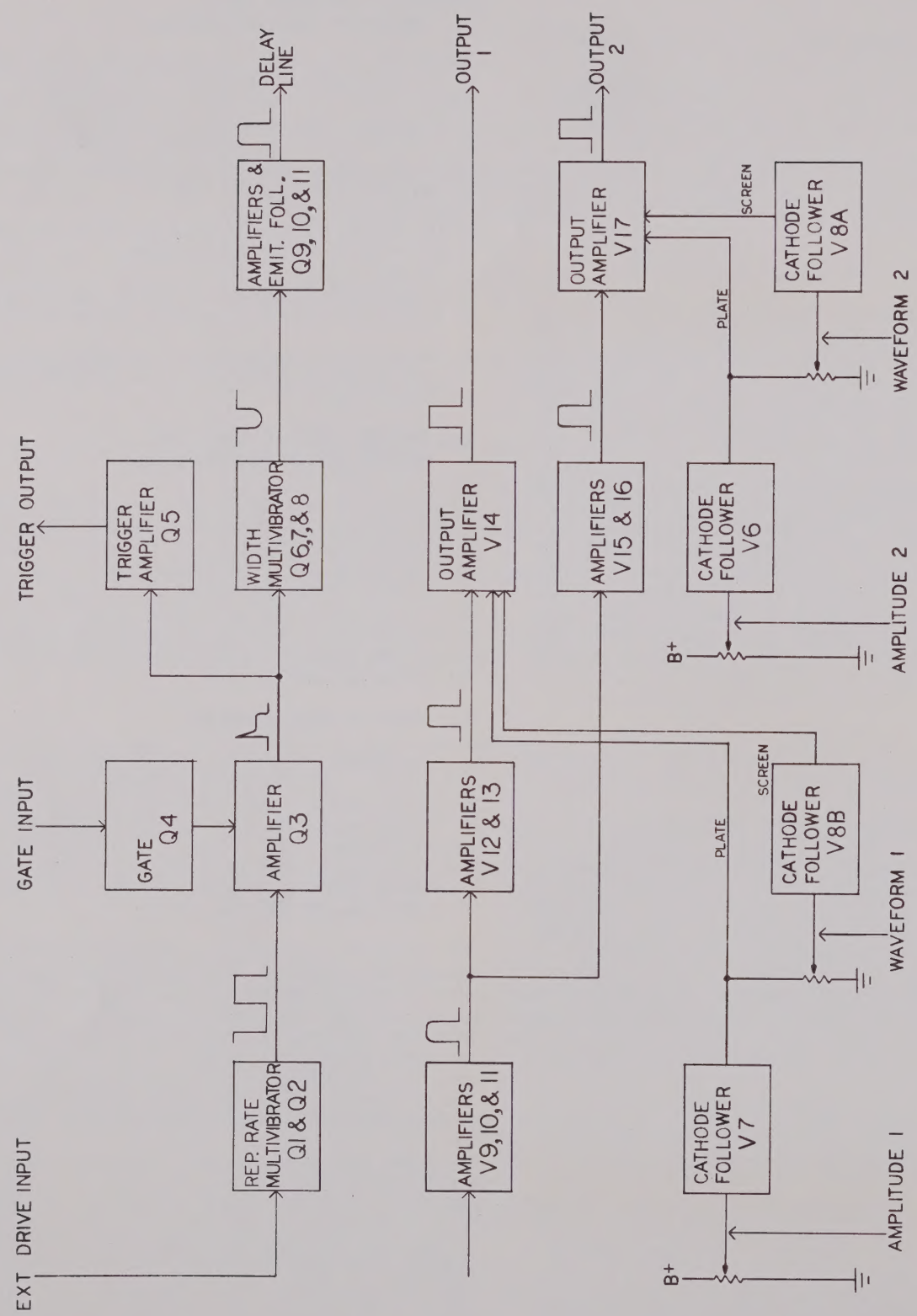

Figure 3-1. Block Diagram - Model 120D Pulse Generator

SECTION III
THEORY OF OPERATION

3.1 GENERAL DESCRIPTION

Refer to figure 3-1, "Block Diagram - Model 120D Pulse Generator." The internal pulse repetition rate is determined by a free-running multivibrator capable of very fast operation. With the FREQ. RANGE selector set to EXT. DRIVE, the multivibrator is switched to a Schmitt trigger configuration and the pulse repetition rate is determined by the external trigger repetition rate. The output of the multivibrator is then amplified. The amplifier is biased off and the pulse chain interrupted if a gating signal is applied to the instrument. The output of the amplifier is coupled both to a monostable multivibrator, which determines the pulse width, and to another amplifier, which provides a negative trigger output.

The width multivibrator is non-saturating and provides a negative pulse output, the width of which is set by the front panel width controls. This pulse then goes through two stages of transistorized amplification and is delayed approximately 100 nanoseconds by a 50 ohm delay line before being applied to the shaping chain.

Five stages of transformer-coupled, Class C amplification serve to "square" the pulse until it has a rise time of 1 nanosecond or less. The first three stages of amplification are common to both pulse 1 and pulse 2. However, the shaping chain divides after the third amplifier, and the final shaping stages are independent for each output channel. Each output tube provides an independent output which is brought out to a front panel BNC connector. The amplitude of the output pulse is determined by the plate and screen voltage of the output tube. This is continuously and independently variable for each of the output tubes. The waveform adjustments on the rear panel of the instrument determines the plate to screen voltage ratio of the output tubes.

There are four regulated power supplies. There is a high voltage supply for the shaping chain and output tubes and two low voltage supplies for the transistorized timing circuitry. These supplies are conventional feedback regulated. The fourth supply is established across a 9.1 volt zener diode. This supply is used for biasing the shaping chain and output tubes.

3.2 REPETITION RATE MULTIVIBRATOR

Q1 and Q2 comprise a free-running multivibrator capable of running at very fast repetition rates. To understand the operation of this multivibrator, assume that switching is as shown on the schematic and the timing capacitor has charged up to some positive value. Q1 is consequently turned off and Q2 is forced into conduction by the negative bias obtained through R1, R7 and CR1. The timing capacitor on the base of Q1 will discharge through variable resistor R53 and R6 to the negative voltage level at base of Q2.

It is important to note that because Q2 is conducting there is a voltage drop across R5 and, consequently, the emitter voltage of Q2 is less than the emitter voltage of Q1. Thus, the timing capacitor on the base of Q1 will discharge to the voltage level at the base of Q2 until such time as the base emitter drop of Q1 becomes less than the base emitter drop of Q2. Q1 will then start to conduct; its collector voltage will start to go positive; and this in turn will cause the base of Q2 to go positive, forcing it out of conduction.

The timing capacitor now takes on charge due to the difference in potential between bases. As the capacitor charges, Q1 remains in conduction until difference in potential between bases is slightly less than bias developed across R2. When this occurs, Q2 is forced back into conduction and Q1 becomes cut off.

3.3 AMPLIFIER & GATE

Q3 and Q4 comprise an amplifier and gate. In quiescent condition without the presence of a gate signal, both Q3 and Q4 are non-conducting. The biases which determine the cut-off condition of these transistors are developed across the forward resistance of several diodes. The emitters of both Q3 and Q4 are held slightly positive by the forward resistance of diode CR4. The bases are biased more positive than the emitters by the forward resistance of two diodes in series. The negative pulse output of the multivibrator is amplified by Q3 when a gating signal is not present. When a negative 5 volt gating signal is applied to the base of Q4, the common emitters of Q3 and Q4 are held several volts negative. Q3, then, cannot conduct and the pulse chain is interrupted

as long as the gating signal is applied. Zener diode CR6, which zeners at 3.3 volts, protects the base of Q4 from being driven too far negative by large amplitude gating signals.

3.4 TRIGGER OUTPUT

The amplifier output is capacitively coupled to Q5, the trigger output amplifier. Q5 produces a sharp negative trigger spike, approximately 4 volts in amplitude, which is delivered to the front panel through a 510 ohm resistor.

3.5 WIDTH MULTIVIBRATOR

The output of amplifier Q3 is directly coupled to the width multivibrator, comprised of Q6, Q7, and Q8. Q8 is a low impedance source for driving the timing capacitors, while Q6 and Q7 form a monostable multivibrator. In the stable condition Q7 is biased on -- the bias being developed across the forward resistance of diode CR11. With Q7 on, Q6 is forced into non-conduction.

The input to the multivibrator is the base of Q8. It is an emitter follower, and whenever a positive input pulse is received from the previous stage, it is coupled through Q8 and one of the timing capacitors to the base of Q7. Q7, which is normally conducting, is cut off by the positive swing and Q6 is forced into conduction. As Q6 goes into conduction, its collector voltage goes positive. The collector of Q6 is tied to the base of Q8 so the action becomes regenerative. The repetition rate multivibrator then remains in its quasi-stable state until the timing capacitor has discharged through variable resistor R55 and resistor R54. Variable resistor R55 controls the discharge time and serves as the FINE WIDTH control.

The output of the width multivibrator is a small negative pulse taken from the collector of Q7. The width of this pulse is determined by the quasi-stable period of the multivibrator which is, in turn, set by the front panel width controls. This negative pulse is coupled to the base of the following amplifier Q9.

3.6 TRANSISTOR AMPLIFIERS

Q9 and Q10 amplify the positive output of the width multivibrator. Emitter follower Q11 sets the base and emitter voltages of Q9 so that the output pulse is at the exact voltage level needed for the input to the vacuum tube amplifying and shaping chain which follows. The output of the amplifier is delayed approximately 100 nanoseconds by a delay line before it reaches the grid of the first shaping tube.

3.7 AMPLIFIER & SHAPING CHAIN

Tubes V9-V13, V14 and V15 are transformer coupled Class C amplifiers. The pulse output from the timing circuitry is successively amplified and shaped by tubes V9 through V11. The chain then splits with the output of V11 being coupled simultaneously to V12 and V15. These tubes, along with V13 and V16, provide further amplification and shaping of the pulse until a rise time of 1 nanosecond or less can be achieved at the outputs.

3.8 OUTPUT STAGES

The outputs of V13 and V16, final tubes in the shaping chains, are transformer coupled to the grids of the two output tubes V14 and V17, respectively. The output tubes are operated Class C and are independent of one another -- having separate amplitude and waveform controls. Amplitude of the output pulse is determined by simultaneously varying plate and screen voltage of the output tube. V6 and V7 are the cathode followers that supply plate voltage. The output of V6 is divided down by R231 and R232 and fed to one-half of cathode follower V8, which supplies screen voltage to V17. The ratio of plate voltage to screen voltage is determined by R231, the waveform control for output 2. Variable resistor R236 serves similarly as the waveform control for output 1.

The output pulses are AC coupled through parallel capacitors and short lengths of RG 141/U, 50 ohm cable, to the output connectors. Considerable care has been taken in the design and construction of the output section to eliminate ground loops, spurious oscillations, and rise time degrading effects. Component placement, lead length, and lead dress are vital to the best operation of the instrument and should be duplicated as closely as possible when component replacements are made.

3.9 POWER SUPPLY

There are four regulated supplies in the 120D: a +150 volt supply for the shaping chain and output section; a -9 volt supply for biasing amplifiers in the shaping chain; and transistor supplies of +5.1 and -5.1 volts.

The +150 volt supply operates conventionally and is composed of three 6080 regulators in parallel, a 6AU6 control tube, and a 5651 VR tube. The +150 volts is set by variable resistor R211.

The -9.1 volt supply is simply developed across a 9.1 volt zener diode. Each low voltage transistor supply is composed of a series regulator and a feedback amplifier. Both supplies are referenced to a 6.2 volt zener diode. The +5.1 volt level and the -5.1 volt level are both set simultaneously by dividing the reference voltage through variable resistor R244 and fixed resistor R245.

The duty cycle limiter is composed of an overload relay, a reset button, and an overload indicator light. The overload relay monitors the current through R230 and R238, the cathode resistors of V6 and V7, respectively. When this current becomes excessive -- indicating a duty cycle greater than 15 per cent -- the relay trips and the plate and screen supplies of the amplifier chain and output tubes are disengaged. Hold current for the relay is taken from the raw supply to the transistorized voltage regulator.

SECTION IV
MAINTENANCE & CALIBRATION

4.1 COMPONENTS

Top quality components and precision manufacturing methods have been used in this instrument to insure a long life with a minimum of maintenance. The only selected components are electron tubes V14 and V17. These tubes are selected in-circuit at the factory and all replacements must be ordered from the factory or through your local E-H representative.

It is recommended that all replacement tubes, diodes and transistors be obtained from E-H Research Laboratories. This will insure your getting a satisfactory replacement part. In no event should a tube, transistor, or diode be replaced with one from a different manufacturer --- unless, of course, the replacement is obtained from the factory.

4.2 FAN ASSEMBLY

The E-H Model 120D is cooled by a fan that draws air into the instrument. The fan is life-time lubricated, and no preventive maintenance is necessary. Care should be taken that the air flow into the instrument is not restricted, or the instrument may overheat.

4.3 TEST EQUIPMENT

The following test equipment is recommended for incoming inspection and verifying the performance of the Model 120D.

1) A Tektronix Type 519 oscilloscope or a Tektronix Type 661 with Type 4S1 and 5T1 plug-in units. These oscilloscopes have a rise time of 0.35 nanoseconds and a clean waveform response.

2) A pulse generator having repetition rates to 20 megacycles and pulse widths to 100 nanoseconds and at least a negative 4 volt output amplitude, such as another E-H Model 120D.

3) An oscilloscope having a rise time of 12 nanoseconds or better such as the Tektronix 541 with Type L plug-in.

4) A pulse generator having pulse widths to at least 10 microseconds, repetition rates to at least 100 Kc, and a negative output pulse at least 5 volts in amplitude with a rise time of 10 nanoseconds or less such as the E-H Models 130, 131, 132A, or 138 pulse generators.

For servicing, the following additional equipment is recommended.

1) An oscilloscope having a rise time of 4 or 5 nanoseconds such as the Tektronix Model 581 or 585 with a Type 80 plug-in (in place of item 3 above).

2) A d-c voltmeter having an accuracy of 1 per cent or better such as the E-H Model 230 electrometer voltmeter.

4.4 PERFORMANCE CHECK

A complete performance check of the Model 120D can be made without removing the top or bottom dust covers. Observe either output pulse on the Tektronix 519 or 661 oscilloscope. Care must be taken in connecting either of these oscilloscopes to the 120D in order to preserve the pulse waveform. Figures 4-1, 4-2, and 4-3 indicate the recommended coupling method when using the recommended oscilloscopes and also the HP 185A/B. Because the HP 185A/B is specified as having up to 5 per cent overshoot, it is difficult to accurately measure the pulse characteristics of the Model 120D on it.

1) At any convenient conditions of repetition rate and pulse width, observe the output pulse characteristics of both channels. At 10 volts pulse amplitude the rise should be less than 0.85 nanosecond when the waveform control is adjusted for best waveform. Similarly, at 20 volts the rise time should be less than 1.5 nanoseconds. When measuring rise time, it is important to take into consideration the rise time of the oscilloscope.

For gaussian functions rise time observed on the oscilloscope is, to a first approximation, equal to the square root of the sum of the squares of oscilloscope rise time and pulse rise time of the Model 120D.

For example:

Observed rise time = 0.8 nanoseconds

Scope rise time = 0.35 nanoseconds

Pulse rise time $= \sqrt{(0.8)^2 - (0.35)^2}$

$= \sqrt{0.64 - 0.12}$

$= \sqrt{0.52}$

= 0.72 nanoseconds

The word "gaussian" is underlined in the previous paragraph because some sampling oscilloscopes do not have a gaussian rise. With these samplers the effect of the oscilloscope on the rise time being measured cannot be taken into account so simply. The Tektronix Type 519 and 661 do have an approximate gaussian rise.

Other pulse characteristics you are likely to observe on a 10 volt pulse are:

a. Approximately 0.6 volt preshoot.

b. Pulse top distortion of less that 1 volt peak-to-peak. This distortion occurs in the first 10 or 15 nanoseconds of the pulse, and its shape is somewhat variable by the waveform control. The remainder of the pulse top is essentially free of distortion.

c. Distortion of approximately 1 volt peak-to-peak amplitude of the base line immediately after the pulse.

d. No sag.

e. No ringing.

f. Variable overshoot (waveform controls).

If both channels appear to have some characteristic appreciably different than listed above, the cause can usually be traced to the measuring apparatus. Reflections that have a period of 5 nanoseconds may be traceable to a mismatch at instrument output connector (i.e. defective attenuator, connector, cable, etc.) since 5 nanoseconds is the approximate two-way propagation time of the internal cable which connects the plate of the output tube to the output connector.

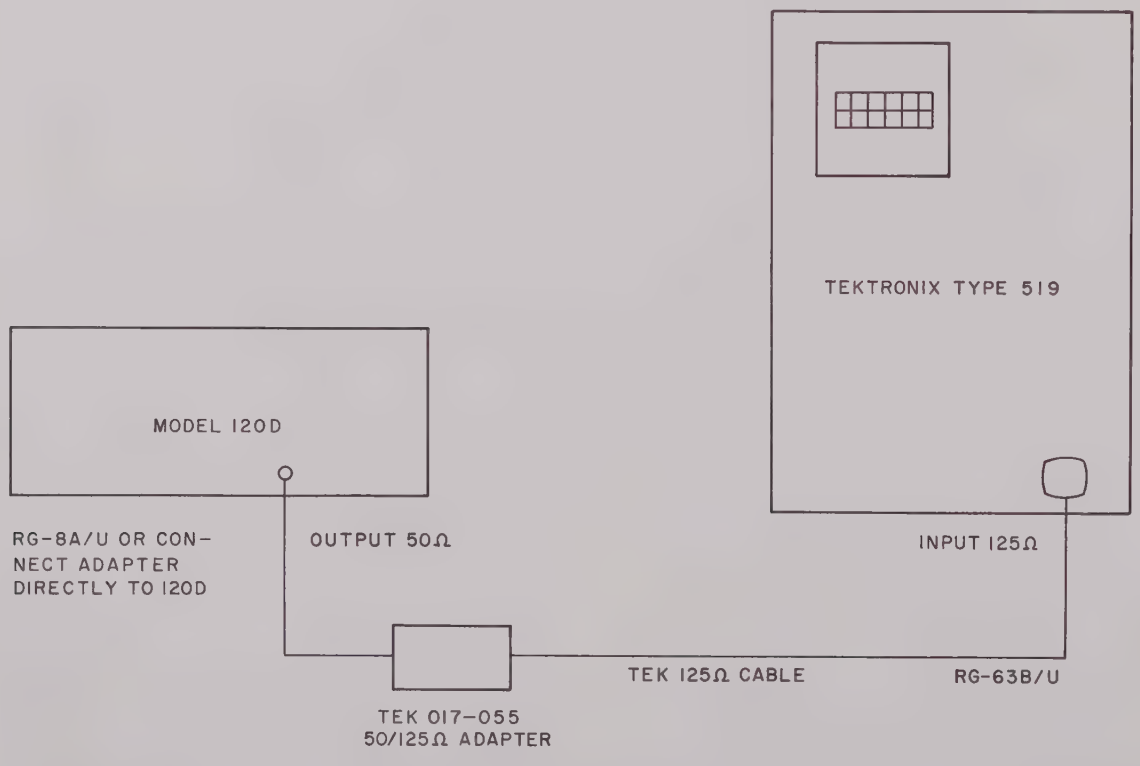

Figure 4-1. Recommended Coupling Method When Using Tektronix 519

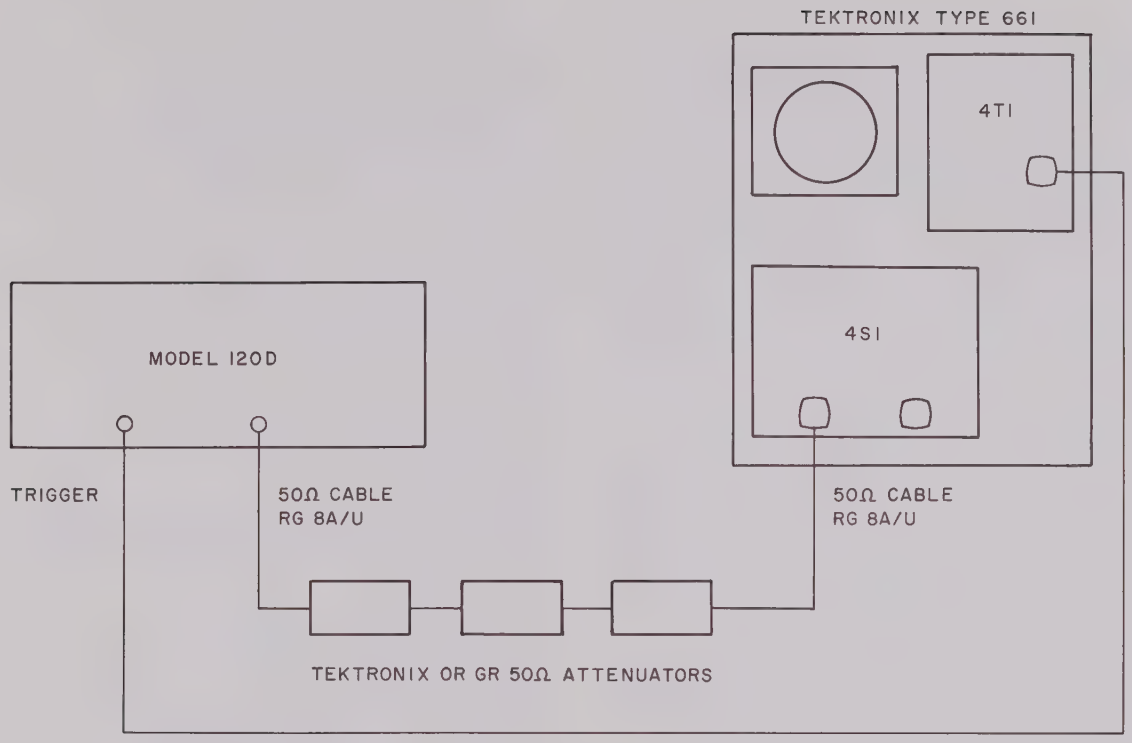

Figure 4-2. Recommended Coupling Method When Using Tektronix Type 661

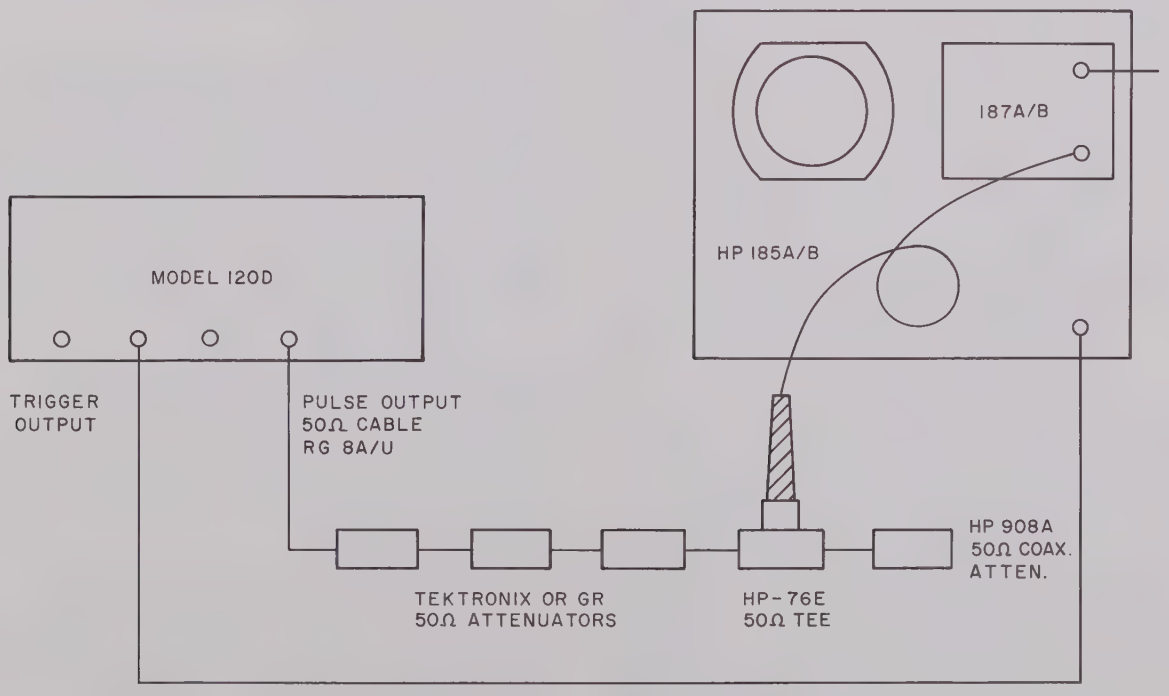

Figure 4-3. Recommended Coupling Method When Using HP 185A/B

On the Tektronix 519 excessive overshoot can appear if the internal delay line termination is defective. A reflection with a period of approximately 120 nanoseconds indicates a defective termination.

2) Check the repetition rate ranges for overlap from range to range. The maximum repetition rate should be greater than 20 mc. Note that 15% duty cycle limits the maximum pulse width at higher frequencies.

3) At a low repetition rate (less than 1 megacycle) check the range of width control. Pulse widths of less than 10 nanoseconds to greater than 100 nanoseconds should be available.

4) Set the pulse width to exactly 100 nanoseconds, the amplitude to 20 volts, and increase the repetition rate so as to obtain a 15 per cent duty cycle (1.5 mc). Observe that the droop is no greater than approximately 5 per cent and that the pulse waveform is still clean. (Under these test conditions, the pulser is generating 1.2 watts and can destroy external 1 watt attenuators.) Increase the repetition rate further and observe that the overload circuit is activated.

5) With the TRIGGER OUTPUT unterminated, observe the trigger output on the Tektronix Model 541 or 581. The pulse should be negative, approximately 4 volts in amplitude, and 100 nanoseconds wide at low repetition rates.

6) Set FREQ. RANGE to EXT. and adjust a second Model 120D to provide a negative pulse, 4 volts in amplitude to the EXTERNAL DRIVE connector on the 120D under test. The output of the 120D under test should be a pulse train, the repetition rate of which is controlled by the drive pulser.

NOTE

The fine frequency control of the pulser under test will operate as an external drive sensitivity control. Turned fully clockwise, the fine frequency control will cause the pulser under test to free-run. As the control is turned counterclockwise, the sensitivity is decreased.

7) Set the Model 120D controls to obtain an output pulse repetition rate of approximately 1 megacycle, and a pulse width of approximately 20 nanoseconds. Adjust a gating pulse generator (E-H Model 130, 131, 132A, or 138 pulse generators) to provide a negative output pulse, 5 volts in amplitude and approximately 10 microseconds wide at any convenient repetition rate. Connect the output of the gating pulse generator to the GATE INPUT connector. Synchronize a Tektronix 541, 581, or equivalent on the gating pulse generator and observe the gated output of the pulser under test. The pulse train should be interrupted during the period that the gating pulse is applied to the GATE INPUT connector.

4.5 LOCALIZING A MALFUNCTION

Usually the nature of a malfunction will lead one immediately to suspect the circuit which has failed. For instance, should the Model 120D operate improperly on one frequency range, the trouble is known to exist in the repetition rate multivibrator circuitry.

If there is no pulse output, the following steps will help locate the source of malfunction.

1) POWER SUPPLY. - Check the power supply voltages.

a. The low voltage supplies should be 5.1 volts ±2 per cent. If not, adjust R244. Ripple should be less than 25 millivolts peak-to-peak.

b. The 9.1 volt supply should be within ±10 per cent tolerance and the ripple should be less than 25 millivolts peak-to-peak.

c. The B+ supply should be +150 volts. If not, adjust R211. Ripple should be less than 25 millivolts peak-to-peak.

2) TIMING CIRCUITRY. - Observe the pulse at the collector of Q10. If this pulse is present as indicated on the schematic diagram, the timing circuitry is functioning and the malfunction must exist in the output circuitry. No pulse, or a significantly different pulse waveform than indicated on the schematic, indicates the malfunction exists on the timing board or on the repetition rate and width switches.

3) OUTPUT CIRCUITRY. - Compare the grid and plate waveforms of each output tube with that indicated on the schematic diagram. This should localize the particular tube or associated circuit which is malfunctioning. If only one output channel is malfunctioning, the cause must be in the final three amplifier stages of that channel.

4.6 SERVICING

1) POWER SUPPLY. - Any malfunction of the power supply will usually be traced to a weak tube or transistor, or possibly a defective rectifier diode. Electrolytic capacitors will, of course, require periodic replacement.

2) TIMING CIRCUITRY. - An extender board (E-H Part No. 10291-02) will simplify servicing of the timing circuit.

a. Repetition Rate Multivibrator. To observe the operation of the repetition rate multivibrator, monitor the waveform on the collector of Q2 with the 100 megacycle oscilloscope. This waveform should be as indicated on the schematic. Absence of the waveform indicates that the multivibrator is not operating. This is probably due to failure of transistor Q1 or Q2, or possibly diode CR1.

The malfunction of a particular frequency range is probably due to a defective frequency range timing capacitor or a dirty switch contact. Capacitor C57 sets the maximum repetition rate and should be adjusted to provide a 20 megacycle pulse rate when observing the output pulse -- not the timing circuit waveform.

b. External Drive. Note that with FREQ. RANGE in the EXT. position, the FINE control acts as a sensitivity control. In the fully clockwise position, the multivibrator will normally free-run. In the fully counterclockwise position, the external drive circuitry is least sensitive. For greatest sensitivity, the FINE control should be adjusted as far clockwise as possible without causing the instrument to free-run.

If the instrument operates properly using internal clock rates but does not drive externally, it is probably because the proper driving voltage is not present at the input connector or because of a defective diode CR51.

c. Gate. Proper operation of the gate depends on transistors Q3 and Q4 and diodes CR2-8. These components should be checked first if the gate malfunctions. Notice that some modulation of the pulse burst envelope is normal during gated operation.

d. Trigger Output. The trigger output is delivered to the front panel jack from the collector of transistor Q5. An improper trigger output is probably due to a defective Q5.

e. Width Multivibrator. The operation of the width multivibrator can best be observed at the base of Q9 and at the base of Q7. These waveforms should be present as indicated on the schematic diagram. A defective transistor or timing capacitor can cause malfunctions. Variable capacitor C58 determines the minimum output pulse width. It is adjusted with the WIDTH selector in the 10-20 nanosecond positions, the FINE control fully counterclockwise, and the repetition rate set below 1 megacycle. C58 should be adjusted to provide an output pulse of 10 nanoseconds width.

f. Transistor Amplifiers. Q9 and Q10 amplify the pulse formed by the width circuitry. Typical waveforms for these amplifiers are shown on the schematic. Q10 is an emitter follower, which determines the clamp voltages of the waveforms. Any appreciable deviation from these voltages could be due to Q11 or diodes CR14 and CR15.

3) OUTPUT CIRCUITRY. - The waveforms shown on the schematic will help localize any malfunction to a particular stage. Any replacement tube in this section of the pulse generator must be Amperex. V14 and V17 are selected, and replacements must be ordered from the factory.

a. Amplitude. The amplitude of the output pulses is determined by R227 and R241 which set the grid voltage of emitter followers V6 and V7 respectively. Waveform adjustments R231 and R236 also will affect the amplitude of the output pulse. If the maximum amplitude output pulse is less than 20 volts it could be due to misadjustment of the waveform control or a defective output tube. Be sure to check that the output tube socket is making connection with all pins of the output tube. A defective V6, V7, R227 or R226 also could cause maximum output voltages less than 20 volts.

b. Duty Cycle Effects. Serious degradation of the pulse waveform at high duty cycles can be caused by any one of the tubes in the output section. If only one output pulse is degraded, the defective tube is one of the final three amplifiers in that stage. If both output pulses are similarly degraded, the problem could be V9, V10, V11, or possibly Q9 or Q10. V9 should be suspected first for low gain. For expediency, the B+ may be increased to +155 volts to eliminate duty cycle effects; however, no greater increase can be tolerated without over-rating the tubes.

c. Waveform and Rise Time. The output pulse waveform is primarily dependent on the output tube V14 or V17. A slow rise time could be caused by any of the tubes or associated circuitry. Note that the WAVEFORM controls typically should be adjustable to provide less than 10 per cent overshoot at all pulse amplitudes of 10 volts or greater.

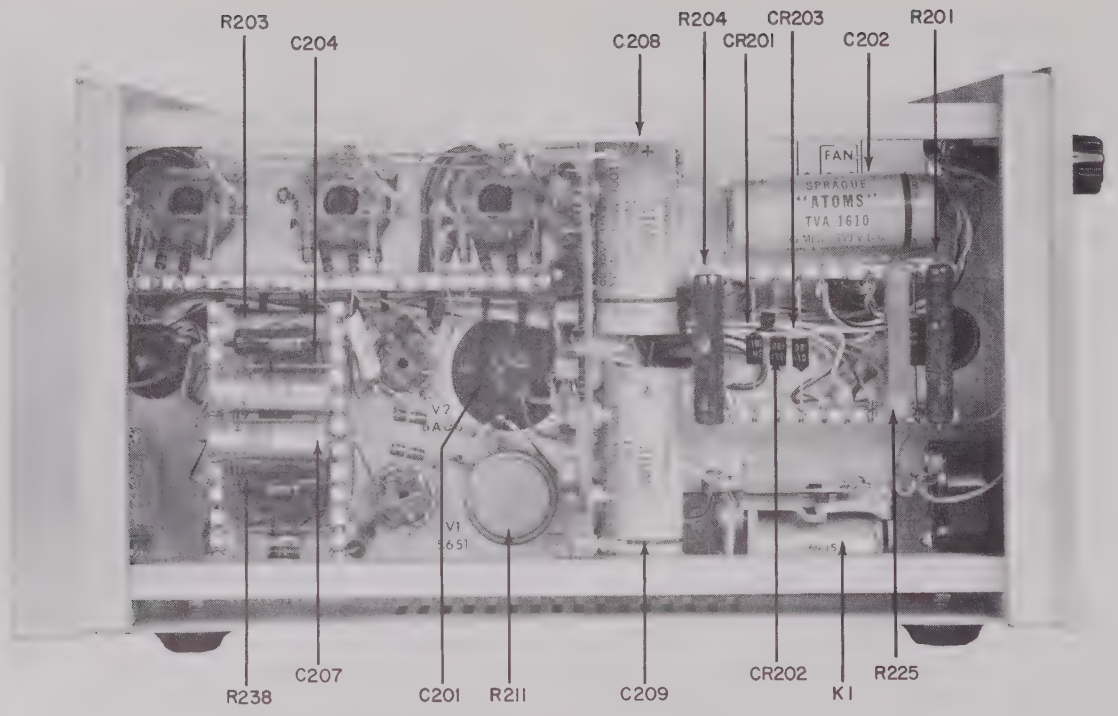

Figure 4-4. Model 120D Power Supply Deck

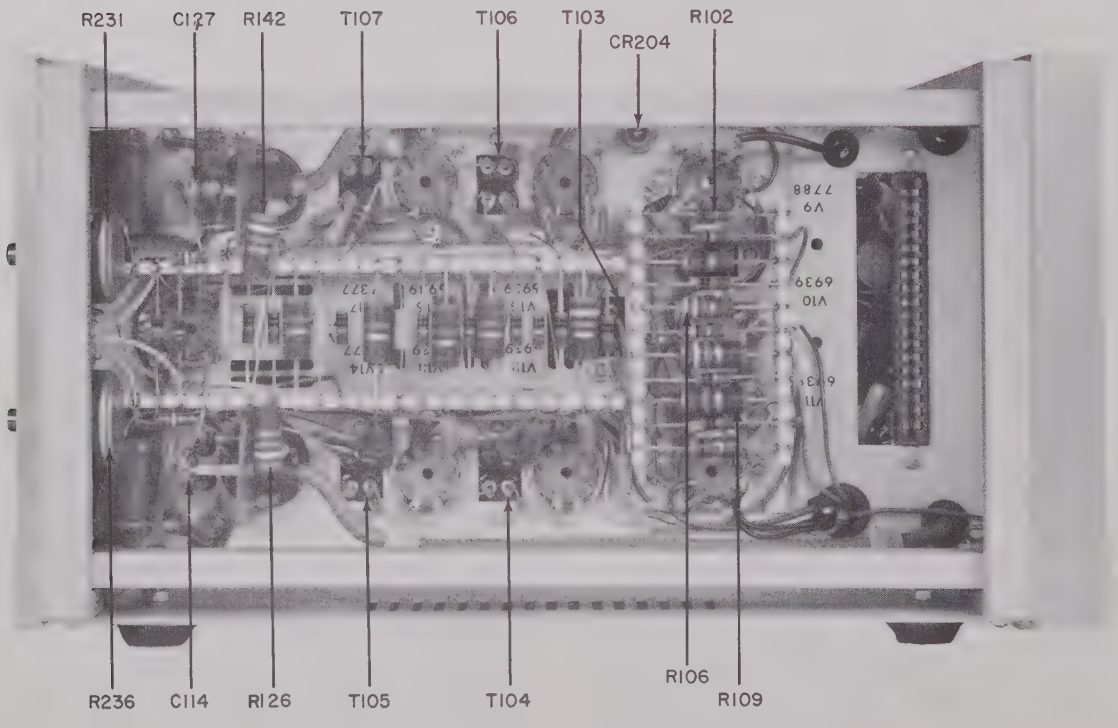

Figure 4-5. Model 120D RF Amplifier Deck

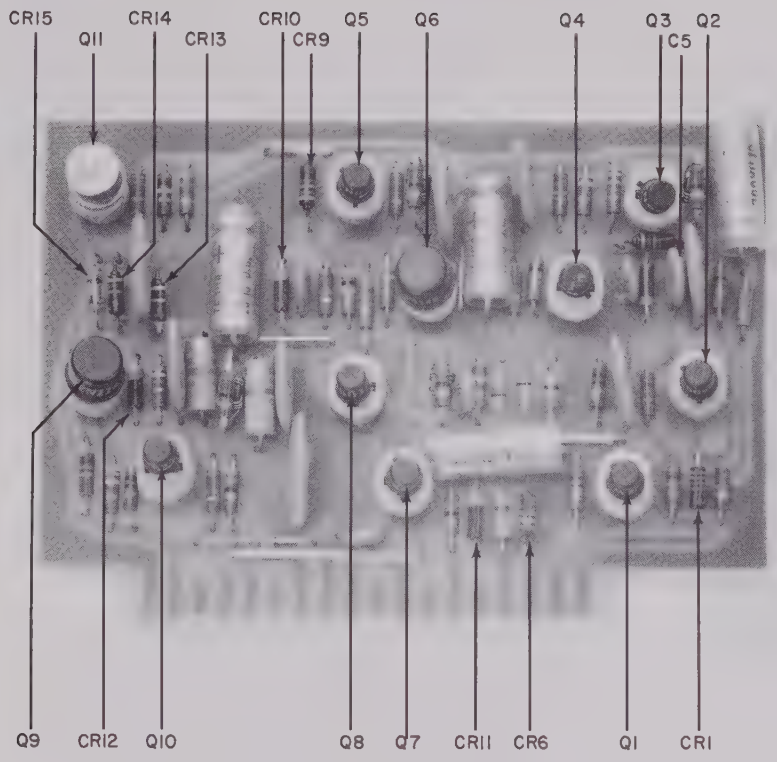

Figure 4-6. Model 120D Timing Circuits

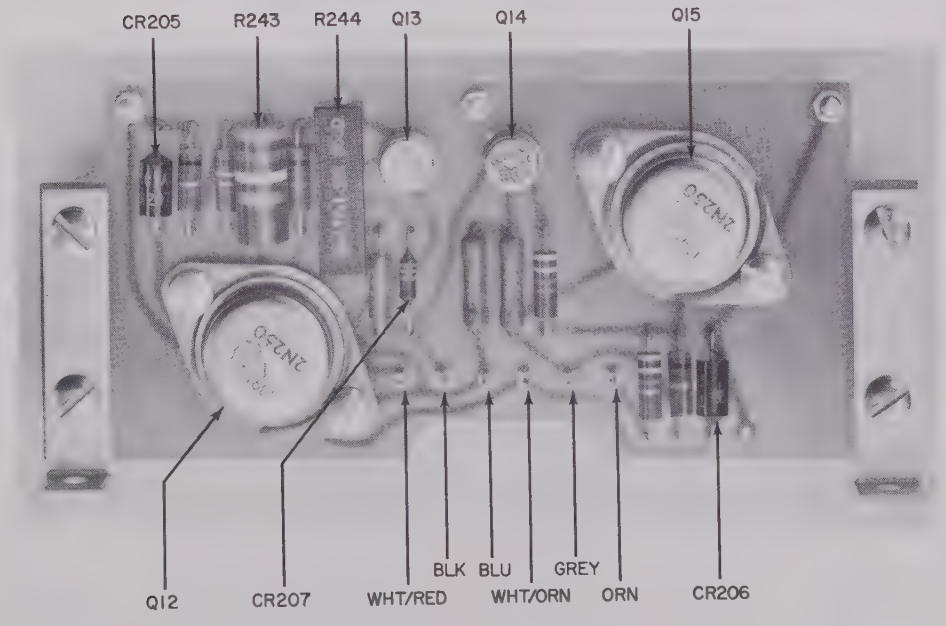

Figure 4-7. Model 120D Low Voltage Power Supply

REVISIONS						
ISSUE	REVISION	DATE	DRAWN	CHK'D	APP'D	E.O.
A	ORIG. ISSUE	7-3-62	Ray	DW		
B	Added R256 & R257 E246	6-3	JT	DW		SEE E.O.

PROPRIETARY INFORMATION

E-H RESEARCH LABORATORIES, INC.

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D-10396 B

TITLE: SCHEMATIC, POWER SUPPLY MODEL 120D — D-10396 B — SHEET NO. 1 OF 1

TRANSFORMER CONNECTION FOR 230V OPERATION

TRANSFORMER SHOWN CONNECTED FOR 115V OPERATION.

NOTES:

1. ALL RESISTANCES GIVEN IN OHMS UNLESS OTHERWISE SPECIFIED.
2. ALL RESISTORS ARE ONE-HALF WATT, 5%, UNLESS OTHERWISE SPECIFIED.
3. ALL CAPACITANCES GIVEN IN MICRO-FARADS UNLESS OTHERWISE SPECIFIED.
4. * TYPICAL VALUE SHOWN. COMPONENT MAY BE A DIFFERENT VALUE OR OMITTED.

WIRE COLOR CODE	
BLACK	BK
BROWN	BN
RED	R
ORANGE	OR
YELLOW	Y
GREEN	GN
BLUE	BU
PURPLE	P
GREY	GY
WHITE	W

POWER SUPPLY OUTPUT

PHYSICALLY LOCATED ON R.F. DECK

AMPLITUDE 2

AMPLITUDE 1

WAVEFORM 2

WAVEFORM 1

OVERLOAD RESET S203

+150V R — B+

+10 TO 150V W-P — PLATE SUPPLY, V14

SCREEN SUPPLY, V14

SCREEN SUPPLY, V17

+10 TO 150V W-OR — PLATE SUPPLY, V17

-51V OR — C-

+5.1V BU — PIN 17

0V BK — PIN 1

-5.1V GY — PIN 14

TIMING CIRCUIT BOARD

PRINTED CIRCUIT BOARD

MATERIAL LIST

QTY	ITEM NO.	PART NO.	DESCRIPTION	SCHEMATIC OR SPEC. REF

E-H RESEARCH LABORATORIES, INC. OAKLAND, CALIFORNIA

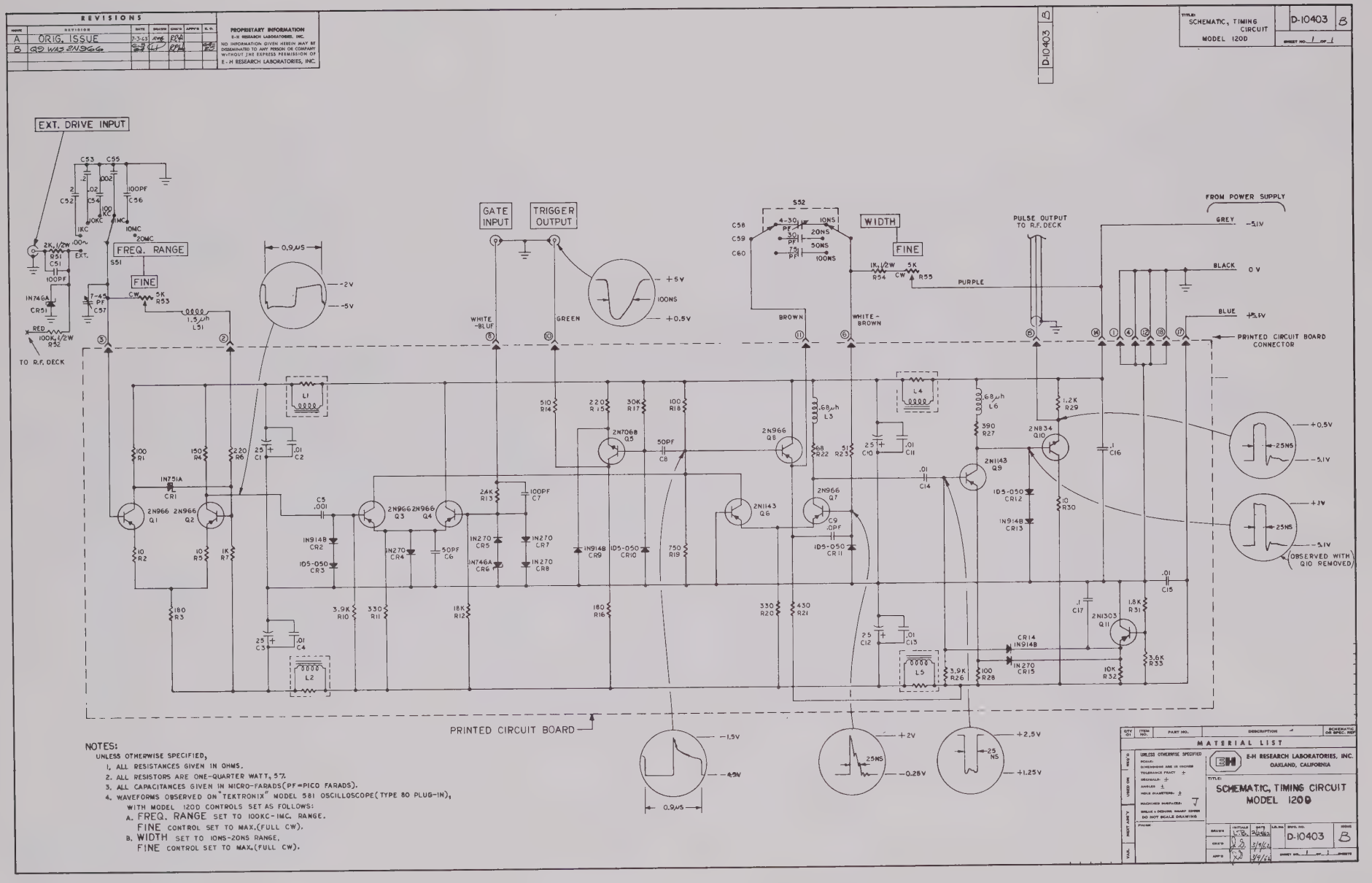
SCHEMATIC, POWER SUPPLY MODEL 120D

D-10396 B

DRAWN — DATE 3/14/62

CHK'D — DATE 3/14/62

APP'D — DATE 3/14/62


REVISIONS
A ORIG. ISSUE
B ADD 2N966
PROPRIETARY INFORMATION
E-H RESEARCH LABORATORIES, INC.
D-10403 B
TITLE: SCHEMATIC, TIMING CIRCUIT MODEL 120D
EXT. DRIVE INPUT
FREQ. RANGE
FINE
GATE INPUT
TRIGGER OUTPUT
WIDTH
PULSE OUTPUT TO R.F. DECK
FROM POWER SUPPLY
GREY -5.1V
BLACK 0 V
BLUE +5.1V
PRINTED CIRCUIT BOARD CONNECTOR
TO R.F. DECK
PRINTED CIRCUIT BOARD
(OBSERVED WITH Q10 REMOVED)
NOTES:
UNLESS OTHERWISE SPECIFIED,
1. ALL RESISTANCES GIVEN IN OHMS.
2. ALL RESISTORS ARE ONE-QUARTER WATT, 5%.
3. ALL CAPACITANCES GIVEN IN MICRO-FARADS(PF=PICO FARADS).
4. WAVEFORMS OBSERVED ON "TEKTRONIX" MODEL 581 OSCILLOSCOPE(TYPE 80 PLUG-IN),
WITH MODEL 120D CONTROLS SET AS FOLLOWS:
A. FREQ. RANGE SET TO 100KC-1MC. RANGE.
FINE CONTROL SET TO MAX.(FULL CW).
B. WIDTH SET TO 10NS-20NS RANGE,
FINE CONTROL SET TO MAX.(FULL CW).
MATERIAL LIST
E-H RESEARCH LABORATORIES, INC.
OAKLAND, CALIFORNIA
SCHEMATIC, TIMING CIRCUIT MODEL 120D
D-10403 B

REVISIONS						
MARK	REVISION	DATE	DRAWN	CHK'D	APP'D	E.O.
A	ORIG. ISSUE	7-3-63	JCMB	RDH		
B	REMOVED C119, C127	11-14-63	JCMB	RDH		AW 12
C	ADDED CIRCUIT PROTECTION IN DELETED LINE 2 117	6-3-64	JCMB	RDH		64 12

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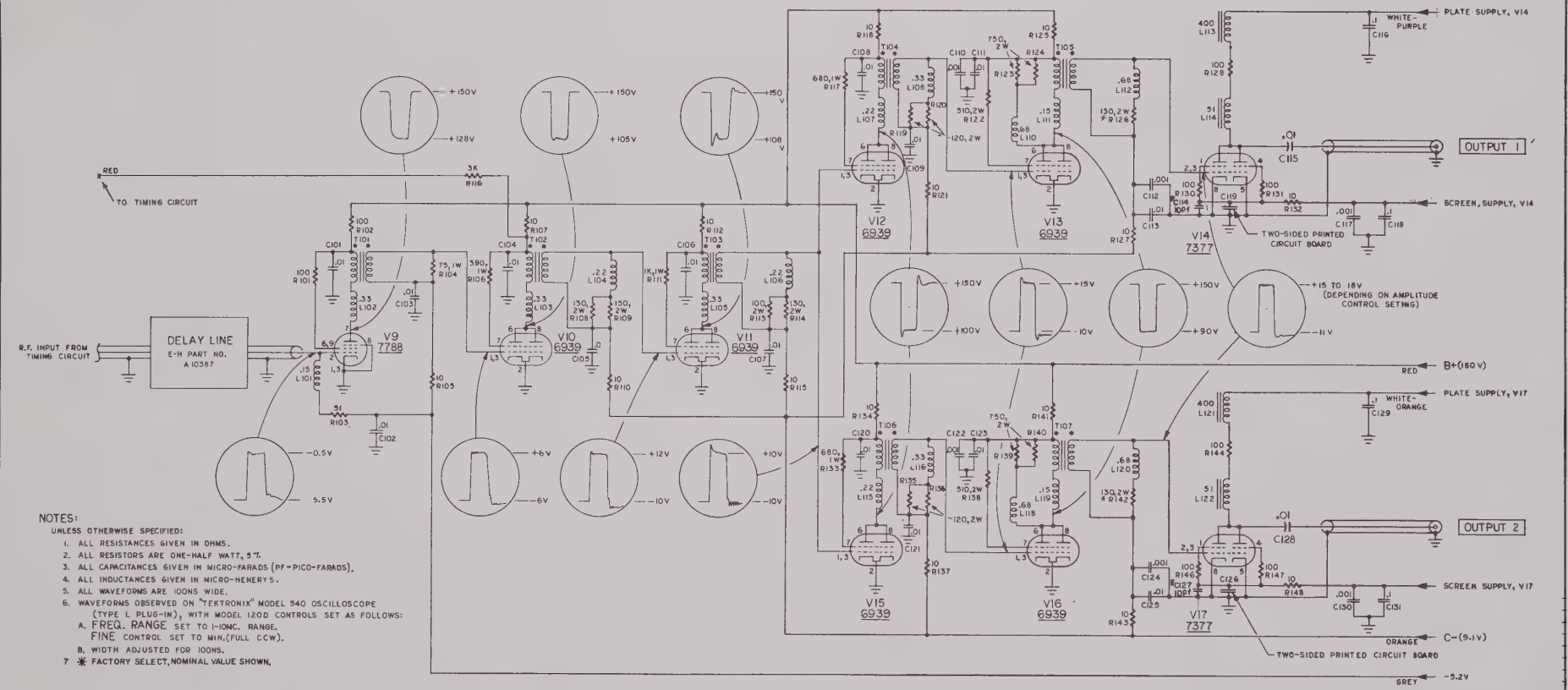
U
D-10412

TITLE: SCHEMATIC, R.F. DECK MODEL 120D — D-10412 C — SHEET NO. 1 OF 1



NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL RESISTANCES GIVEN IN OHMS.
2. ALL RESISTORS ARE ONE-HALF WATT, 5%.
3. ALL CAPACITANCES GIVEN IN MICRO-FARADS (PF=PICO-FARADS).
4. ALL INDUCTANCES GIVEN IN MICRO-HENERYS.
5. ALL WAVEFORMS ARE 100NS WIDE.
6. WAVEFORMS OBSERVED ON "TEKTRONIX" MODEL 540 OSCILLOSCOPE (TYPE L PLUG-IN), WITH MODEL 120D CONTROLS SET AS FOLLOWS:
   A. FREQ. RANGE SET TO 1-10MC. RANGE, FINE CONTROL SET TO MIN.(FULL CCW).
   B. WIDTH ADJUSTED FOR 100NS.
7 * FACTORY SELECT, NOMINAL VALUE SHOWN.

QTY -01	ITEM NO.	PART NO.	DESCRIPTION	SCHEMATIC OR SPEC. REF

MATERIAL LIST

UNLESS OTHERWISE SPECIFIED: SCALE: SCALE DIMENSIONS ARE IN INCHES; TOLERANCE FRACT. ±; DECIMALS ±; ANGLES ±; HOLE DIAMETERS ±; MACHINED SURFACES 7; BREAK 2 ADJOINING SHARP EDGES; DO NOT SCALE DRAWING

E-H RESEARCH LABORATORIES, INC. OAKLAND, CALIFORNIA

TITLE: SCHEMATIC, R.F. DECK MODEL 120D

	INITIALS	DATE	DWG. NO.	ISSUE
DRAWN	LSB	3/8/63	D-10412	C
CHK'D	[illegible]	3/10/64		
APP'D	[illegible]	5/12/64	SHEET NO. 1 OF 1 SHEETS	

SECTION V
PARTS LIST

5.1 ORDERING INFORMATION

To insure your receiving the proper replacement part, please include the following information with your order.

1. Model Number and Serial Number of the instrument for which the replacement part is intended.
2. Circuit Reference of the part.
3. E-H Part Number.

Replacement parts may be ordered through your E-H Representative or from the factory.

5.2 WARRANTY

This instrument is guaranteed to be free from defects in material and workmanship. Our obligation is limited to repairing the instrument should it prove to be defective, upon our examination, within one (1) year after the purchase date. Fuses and batteries are specifically excluded from warranty. Electron tubes, transistors, and diodes are warranted for six (6) months.

For In-Warranty repair of this instrument contact E-H Research Laboratories, Customer Service Department, and provide:

1. Instrument Model Number and Serial Number
2. Full details of the nature of the malfunction

Shipping instructions, or repair information and parts, will be given you promptly.

CUSTOMER SERVICE DEPARTMENT, E-H RESEARCH LABORATORIES, INC.

163 ADELINE STREET, OAKLAND, CALIFORNIA - Phone: TE 4-3030, Area Code 415

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
C1	capacitor, fixed, electrolytic 25 uf, 10 wvdc	316-041
C2	capacitor, fixed, ceramic .01 uf, 600 v	311-012
C3	Same as C1.	
C4	Same as C2.	
C5	capacitor, fixed, ceramic .001 uf, ±10%, 1 KV	311-010
C6	capacitor, fixed, ceramic 50 pf, ±10%, 1 KV	311-006
C7	capacitor, fixed, ceramic 100 pf, ±10%, 1 KV	311-007
C8	Same as C6.	
C9	capacitor, fixed, ceramic 10 pf, ±10%, 1 KV	311-001
C10	Same as C1.	
C11	Same as C2.	
C12	Same as C1.	
C13-15	Same as C2.	
C16-17	capacitor, fixed, ceramic .1 uf, +80-30%, 75 v	311-014
C51	Same as C7.	
C52	capacitor, fixed, metalized, mylar, 2 uf, ±5%, 200 v	320-026
C53	capacitor, fixed, metalized, mylar, .2 uf, ±5%, 200 v	320-024
C54	capacitor, fixed, metalized, mylar, .02 uf, ±5%, 200 v	320-022
C55	capacitor, fixed, metalized, mylar, .002 uf, ±5%, 200 v	320-027
C56	capacitor, fixed, polystyrene 100 pf, ±5%, 500 v	362-002
C57	capacitor, variable 7-45 pf, 500 v, ceramic	332-001
C58	capacitor, variable 4-30 pf, 500 v, ceramic	332-002
C59	capacitor, fixed, ceramic 30 pf, ±20%, 500 v	311-005
C60	capacitor, fixed, ceramic 75 pf, ±10%, 500 v	311-025
C101-109	Same as C2.	
C110	Same as C5.	
C111	Same as C2.	
C112	Same as C5.	
C113	Same as C2.	
C114	capacitor, fixed, ceramic button type, .001 uf, 500 v	317-001
C115	Same as C2.	
C116	capacitor, fixed, ceramic .1 uf, +80-20%, 500 v	311-023
C117	Same as C5.	
C118	Same as C116.	
C119	capacitor, two-sided, printed circuit board	10378-01
C120-121	Same as C2.	
C122	Same as C5.	
C123	Same as C2.	
C124	Same as C5.	
C125	Same as C2.	
C126	Same as C119.	
C127	Same as C114.	
C128	Same as C2.	
C129	Same as C116.	
C130	Same as C5.	
C131	Same as C116.	
C201	capacitor, fixed, electrolytic 250 uf, 300 wvdc	316-040
C202	capacitor, fixed, electrolytic 30 uf, 350 wvdc	316-039
C203	Same as C116.	
C204	capacitor, fixed, electrolytic 10 uf, 250 wvdc	316-002
C205-206	Same as C5.	
C207	Same as C204.	
C208-209	capacitor, fixed, electrolytic 1000 uf, 15 wvdc	316-038
C210-211	capacitor, fixed, electrolytic 25 uf, 25 wvdc	316-028
C212-214	Same as C2.	
C215	Same as C204.	
C216-217	Same as C5.	
CR1	diode, zener, 1N751A, 400 mw, 5.1 v, ±5%	374-022
CR2	diode, 1N914B	376-022
CR3	diode, ID5-050	376-040
CR4-5	diode, 1N270	376-031
CR6	diode, zener, 1N746A, 400 mw, 3.3 v, ±5%	374-017
CR7-8	Same as CR4.	
CR9	Same as CR2.	
CR10-12	Same as CR3.	
CR13-14	Same as CR2.	
CR15	Same as CR4.	
CR51	Same as CR6.	
CR201-203	diode, 1N2071	376-034
CR204	diode, zener, 1N2973RA, 10 w, 9.1 v, ±10%	374-043
CR205-206	Same as CR201.	
CR207	diode, zener, 1N753 400 mw, 6.2 v, ±10%	374-019
Q1-4	transistor, 2N966	663-032
Q5	transistor, 2N706B	663-023
Q6	transistor, 2N1143	663-006
Q7-9	Same as Q1.	
Q10	transistor, 2N834	663-028
Q11	transistor, 2N1303	663-011
Q12	transistor, 2N250	663-026
Q13	transistor, 2N1306	663-018
Q14	transistor, 2N1305	663-017
Q15	Same as Q12.	

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
R1	resistor, fixed, comp., 100 ohms, 5%, 1/4 w	595-101
R2	resistor, fixed, comp., 10 ohms, 5%, 1/4 w	595-100
R3	resistor, fixed, comp., 180 ohms, 5%, 1/4 w	595-181
R4	resistor, fixed, comp., 150 ohms, 5%, 1/4 w	595-151
R5	Same as R2.	
R6	resistor, fixed, comp., 220 ohms, 5%, 1/4 w	595-221
R7	resistor, fixed, comp., 1 K, 5%, 1/4 w	595-102
R10	resistor, fixed, comp., 3.9 K, 5%, 1/4 w	595-392
R11	resistor, fixed, comp., 330 ohms, 5%, 1/4 w	595-331
R12	resistor, fixed, comp., 18 K, 5%, 1/4 w	595-183
R13	resistor, fixed, comp., 2.4 K, 5%, 1/4 w	595-241
R14	resistor, fixed, comp., 510 ohms, 5%, 1/4 w	595-511
R15	Same as R6.	
R16	Same as R3.	
R17	resistor, fixed, comp., 30 K, 5%, 1/4 w	595-303
R18	Same as R1.	
R19	resistor, fixed, comp., 750 ohms, 5%, 1/4 w	595-751
R20	Same as R11.	
R21	resistor, fixed, comp., 430 ohms, 5%, 1/4 w	595-431
R22	resistor, fixed, comp., 68 ohms, 5%, 1/4 w	595-680
R23	resistor, fixed, comp., 51 ohms, 5%, 1/4 w	595-510
R26	Same as R10.	
R27	resistor, fixed, comp., 390 ohms, 5%, 1/4 w	595-391
R28	Same as R1.	
R29	resistor, fixed, comp., 1.2 K, 5%, 1/4 w	595-122
R30	Same as R2.	
R31	resistor, fixed, comp., 1.8 K, 5%, 1/4 w	595-182
R32	resistor, fixed, comp., 3.6 K, 5%, 1/4 w	595-362
R33	resistor, fixed, comp., 10 K, 5%, 1/4 w	595-103
R53	pot., comp., linear taper, 5 K, 10%, 2 w	550-003
R55	pot., multi-turn, ww 10-turn, 5 K, 5%, .25% lin., 2 w	540-006
R104	resistor, fixed, comp., 75 ohms, 5%, 1 w	597-750
R106	resistor, fixed, comp., 390 ohms, 5%, 1 w	597-391
R108	resistor, fixed, comp., 130 ohms, 5%, 2 w	598-131
R109	resistor, fixed, comp., 150 ohms, 5%, 2 w	598-151
R111	resistor, fixed, comp., 1 K, 5%, 1 w	597-102
R113	resistor, fixed, comp., 100 ohms, 5%, 2 w	598-101
R114	Same as R108.	
R117	resistor, fixed, comp., 680 ohms, 5%, 1 w	597-681
R119-120	resistor, fixed, comp., 120 ohms, 5%, 2 w	598-121
R122	resistor, fixed, comp., 510 ohms, 5%, 1 w	597-511
R123-124	resistor, fixed, comp., 750 ohms, 5%, 2 w	598-751
R126	Same as R108.	
R133	Same as R117.	
R135-136	Same as R119.	
R138	Same as R122.	
R139-140	Same as R123.	
R142	Same as R108.	
R201	resistor, fixed, wirewound, 5 ohms, 10%, 10 w	610-017
R202	resistor, fixed, comp., 4.7 ohms, 5%, 1 w	597-047
R204	resistor, fixed, wirewound, 10 ohms, 10%, 10 w	610-016
R209	resistor, fixed, comp., 36 K, 5%, 1 w	597-363
R211	potentiometer, comp., linear taper, locking, 50 K, 10%, 2 w	545-008
R225	resistor, fixed, wirewound, 10 K, 10%, 10 w	610-022
R227	pot., comp, linear taper, 100 K, 10%, 2 w	550-006
R230	resistor, fixed, wirewound, 7.5 K, 10%, 5 w	610-032
R231	Same as R211.	
R236	Same as R211.	
R238	Same as R230.	
R241	Same as R227.	
R243	resistor, fixed, comp., 12 K, 5%, 2 w	598-123
R244	pot., miniature, multi-turn, linear taper, 200 ohm, 10%, 1/2 w, wirewound	551-017
R251	resistor, fixed, carbon film, 511 ohms, 1%, 1/2 w	601-062
R252	resistor, fixed, carbon film, 475 ohms, 1%, 1/2 w	601-061

NOTE: All resistors shown on the schematic which are not listed above are 1/2 watt, ±5%, fixed, carbon composition.

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
L1-2	inductor	10414-01
L3	inductor, fixed, .68 uh, ±20%	335-013
L4-5	Same as L1.	
L6	Same as L3.	
L51	inductor, fixed, 1.5 uh, ±10%	335-001
L101	inductor, fixed, .15 uh, ±20%	335-014
L102-103	inductor, fixed, .33 uh, ±20%	335-010
L104	inductor, fixed, .22 uh, ±20%	335-014
L105	Same as L102.	
L106-107	Same as L104.	
L108	Same as L102.	
L109-110	Same as L3.	
L111	Same as L101.	
L112	Same as L3.	
L113	inductor, 400 uh	10385-01
L114	inductor, 51 uh	10386-01
L115	Same as L104.	
L116	Same as L102.	
L117-118	Same as L3.	
L119	Same as L101.	
L120	Same as L3.	
L121	Same as L113.	
L122	Same as L114.	
V1	electron tube, 5651, voltage reference	670-013
V2	electron tube, 6AU6, pentode	670-010
V3-5	electron tube, 6080, twin triode	670-017
V6-8	electron tube, 7119 twin triode	670-021
V9	electron tube, 7788/E810F, twin triode	670-023
V10-13	electron tube, 6939, twin tetrode	670-025
V14	electron tube, 7377, selected, twin tetrode	670-022
V15-16	Same as V10.	
V17	Same as V14.	
T101	Pulse Transformer	10383-01
T102-107	Same as T101.	
T201	Power Transformer	653-013
	Delay capsule assembly	10387-01
K1	Relay, 2 position, 50 ohm	584-002
S201-202	Switch, Toggle, DPST	630-006
S203	Switch, pushbutton, shorting & indicator light	635-004
DS201-202	Pilot light assembly, neon, red	510-008
	Fan motor	543-001
	Fan blade, 4" ccw	493-002
	Connector, power, 3-prong, chassis receptacle	700-018
	Fuse extractor post	396-001
F201	Fuse, 3 amp, slo-blo	398-003
	Power cable, 3-prong	786-001
	Timing circuit board, complete incl. transistors	120D-2-3
	Extender board, 18 pin (available as accessory)	10291-02
	Connector, printed circuit, 18 pin	743-008

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